

## (12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization  
International Bureau(43) International Publication Date  
2 August 2001 (02.08.2001)

PCT

(10) International Publication Number  
WO 01/55370 A2

- (51) International Patent Classification<sup>7</sup>: C12N 15/11, C07H 21/00, A61K 31/7125
- (21) International Application Number: PCT/US01/02681
- (22) International Filing Date: 26 January 2001 (26.01.2001)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:  
60/178,562 26 January 2000 (26.01.2000) US
- (71) Applicant: HYBRIDON, INC. [US/US]; 345 Vassar Street, Cambridge, MA 02139 (US).
- (72) Inventor: AGRAWAL, Sudhir; 61 Lamplighter Drive, Shrewsbury, MA 01545 (US).
- (74) Agents: KEOWN, Wayne, A. et al.; Hale and Dorr LLP, 60 State Street, Boston, MA 02109 (US).
- (81) Designated States (*national*): AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW.
- (84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).
- Published:**  
— without international search report and to be republished upon receipt of that report
- For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*



WO 01/55370 A2

(54) Title: MODULATION OF OLIGONUCLEOTIDE CpG-MEDIATED IMMUNE STIMULATION BY POSITIONAL MODIFICATION OF NUCLEOSIDES

(57) Abstract: The invention provides methods for modulating the immune response caused by CpG-containing oligonucleotides. The methods according to the invention enable both decreasing the immunostimulatory effect for antisense applications, as well as increasing the immunostimulatory effect for immunotherapy applications.

# **MODULATION OF OLIGONUCLEOTIDE CpG-MEDIATED IMMUNE STIMULATION BY POSITIONAL MODIFICATION OF NUCLEOSIDES**

## **CROSS-REFERENCE TO RELATED APPLICATION**

This application claims priority to U.S. provisional application serial no. 60/178,562, filed January 26, 2001, the entire contents of which are hereby incorporated by reference.

## **BACKGROUND OF THE INVENTION**

### **Field of the invention**

The invention relates to the therapeutic use of oligonucleotides, both in the antisense approach, and as immunostimulatory agents.

### **Summary of the related art**

Oligonucleotides have become indispensable tools in modern molecular biology, being used in a wide variety of techniques, ranging from diagnostic probing methods to PCR to antisense inhibition of gene expression. This widespread use of oligonucleotides has led to an increasing demand for rapid, inexpensive and efficient methods for synthesizing oligonucleotides.

The synthesis of oligonucleotides for antisense and diagnostic applications can now be routinely accomplished. See e.g., *Methods in Molecular Biology, Vol 20: Protocols for Oligonucleotides and Analogs* pp. 165-189 (S. Agrawal, Ed., Humana Press, 1993); *Oligonucleotides and Analogues: A Practical Approach*, pp. 87-108 (F. Eckstein, Ed., 1991); and Uhlmann and Peyman, *supra*. Agrawal and Iyer, *Curr. Op. in Biotech.* 6: 12 (1995); and *Antisense Research and Applications* (Crooke and Lebleu, Eds., CRC Press, Boca Raton, 1993). Early synthetic approaches included phosphodiester and phosphotriester chemistries. Khorana et al., *J. Molec. Biol.* 72: 209 (1972) discloses phosphodiester chemistry for oligonucleotide synthesis. Reese, *Tetrahedron Lett.* 34: 3143-3179 (1978), discloses phosphotriester chemistry for synthesis of oligonucleotides and polynucleotides. These early approaches

have largely given way to the more efficient phosphoramidite and H-phosphonate approaches to synthesis. Beaucage and Caruthers, *Tetrahedron Lett.* 22: 1859-1862 (1981), discloses the use of deoxynucleoside phosphoramidites in polynucleotide synthesis. Agrawal and Zamecnik, U.S. Patent No. 5,149,798 (1992), discloses optimized synthesis of oligonucleotides by the H-phosphonate approach.

Both of these modern approaches have been used to synthesize oligonucleotides having a variety of modified internucleotide linkages. Agrawal and Goodchild, *Tetrahedron Lett.* 28: 3539-3542 (1987), teaches synthesis of oligonucleotide methylphosphonates using phosphoramidite chemistry. Connolly et al., *Biochemistry* 23: 3443 (1984), discloses synthesis of oligonucleotide phosphorothioates using phosphoramidite chemistry. Jager et al., *Biochemistry* 27: 7237 (1988), discloses synthesis of oligonucleotide phosphoramidates using phosphoramidite chemistry. Agrawal et al., *Proc. Natl. Acad. Sci. USA* 85: 7079-7083 (1988), discloses synthesis of oligonucleotide phosphoramidates and phosphorothioates using H-phosphonate chemistry.

More recently, several researchers have demonstrated the validity of the antisense approach to therapeutic treatment of disease. Crooke, *Antisense Nucleic Acid Drug Dev.* 8: vii-viii, discloses the successful marketing approval of a phosphorothioate oligonucleotide for the treatment of human cytomegalovirus-induced retinitis. Unfortunately, the use of phosphorothioate oligonucleotides has become more complex than originally expected. Certain effects caused by phosphorothioate oligonucleotides could not be explained by the expected antisense mechanism. For example, McIntyre et al., *Antisense Res. Dev.* 3: 309-322 (1993) teaches that a "sense" phosphorothioate oligonucleotide causes specific immune stimulation. This and other side effects have complicated the picture for phosphorothioate oligonucleotides.

On the other hand, the observation that phosphodiester and phosphorothioate oligonucleotides can induce immune stimulation has created interest in developing this side effect as a therapeutic tool. These

efforts have focussed on phosphorothioate oligonucleotides containing the dinucleotide CpG. Kuramoto *et al.*, Jpn. J. Cancer Res. 83: 1128-1131 (1992) teaches that phosphodiester oligonucleotides containing a palindrome that includes a CpG dinucleotide can induce interferon-alpha and gamma synthesis and enhance natural killer activity. Krieg *et al.*, Nature 371: 546-549 (1995) discloses that phosphorothioate CpG-containing oligonucleotides are immunostimulatory. Liang *et al.*, J. Clin. Invest. 98: 1119-1129 (1996) discloses that such oligonucleotides activate human B cells. Moldoveanu *et al.*, Vaccine 16: 1216-1224 (1998) teaches that CpG-containing phosphorothioate oligonucleotides enhance immune response against influenza virus. McCluskie and Davis, The Journal of Immunology 161: 4463-4466 (1998) teaches that CpG-containing oligonucleotides act as potent adjuvants, enhancing immune response against hepatitis B surface antigen.

These reports make clear that there is a need to be able to modulate the immune response caused by CpG-containing oligonucleotides. Ideally, such modulation should include decreasing the immunostimulatory effect for antisense applications, as well as increasing the immunostimulatory effect for immunotherapy applications.

### **BRIEF SUMMARY OF THE INVENTION**

The invention provides methods for modulating the immune response caused by CpG-containing oligonucleotides. The methods according to the invention enables both decreasing the immunostimulatory effect for antisense applications, as well as increasing the immunostimulatory effect for immunotherapy applications. Thus, the invention further provides oligonucleotides having optimal levels of immunostimulatory effect for either application and methods for making and using such oligonucleotides.

The present inventor has surprisingly discovered that positional modification of CpG-containing oligonucleotides dramatically affects their immunostimulatory capabilities. In particular, 3' alkylation or alkoxylation of oligonucleotides, or introduction of an uncharged internucleoside linkage, at particular positions 5' or 3' to the CpG dinucleotide either enhances or reduces their immunostimulatory effect in a reproducible and predictable manner.

In a first aspect, the invention provides a method for reducing the immunostimulatory effect of a CpG-containing oligonucleotide. The method according to this aspect of the invention comprises introducing a 3' substituted nucleoside into the oligonucleotide at a position adjacent to, and on the 5' and/or 3' side of the CpG dinucleotide. In preferred embodiments, this method includes creating a 2'-5' linkage between the 2' position of a 3' substituted nucleoside and the 5' position of another nucleoside, which may or may not be a 3' substituted nucleoside.

In a second aspect, the invention provides a CpG-containing oligonucleotide having a reduced immunostimulatory effect, wherein the oligonucleotide comprises a 3' substituted nucleoside at a position adjacent to, and on the 5' and/or 3' side of the CpG dinucleotide. In preferred embodiments, CpG-containing oligonucleotides according to this aspect of the invention include a 2'-5' linkage between the 2' position of a 3' substituted nucleoside and the 5' position of another nucleoside, which may or may not be a 3' substituted nucleoside.

In a third aspect, the invention provides a method for obtaining an antisense-specific reduction in the expression of a gene in a mammal, the method comprising administering to the mammal a CpG-containing oligonucleotide having a reduced immunostimulatory effect, wherein the oligonucleotide comprises a 3' substituted nucleoside at a position adjacent to, and on the 5' and/or 3' side of the CpG dinucleotide. In preferred embodiments, CpG-containing oligonucleotides used in this aspect of the invention include a 2'-5' linkage between the 2' position of a 3' substituted nucleoside and the 5' position of another nucleoside, which may or may not be a 3' substituted nucleoside.

In a fourth aspect, the invention provides a method for reducing the immunostimulatory effect of a CpG-containing oligonucleotide. The method according to this aspect of the invention comprises introducing an uncharged internucleoside linkage into the oligonucleotide at a position adjacent to, and on the 5' side of the CpG dinucleotide.

In an fifth aspect, the invention provides a CpG-containing oligonucleotide having a reduced immunostimulatory effect, wherein the oligonucleotide comprises an uncharged internucleoside linkage at a position adjacent to, and on the 5' side of the CpG dinucleotide.

In a sixth aspect, the invention provides a method for obtaining an antisense-specific reduction in the expression of a gene in a mammal, the method comprising administering to the mammal a CpG-containing oligonucleotide having a reduced immunostimulatory effect, wherein the oligonucleotide comprises an uncharged internucleoside linkage at a position adjacent to, and on the 5' side of the CpG dinucleotide.

In a seventh aspect, the invention provides a method for reducing the immunostimulatory effect of a CpG-containing oligonucleotide. The method according to this aspect of the invention comprises introducing a 2'-5' internucleoside linkage into the oligonucleotide at a position adjacent to, and on the 5' side of the CpG dinucleotide.

In an eighth aspect, the invention provides a CpG-containing oligonucleotide having a reduced immunostimulatory effect, wherein the

oligonucleotide comprises a 2'-5' internucleoside linkage at a position adjacent to, and on the 5' side of the CpG dinucleotide.

In a ninth aspect, the invention provides a method for obtaining an antisense-specific reduction in the expression of a gene in a mammal, the method comprising administering to the mammal a CpG-containing oligonucleotide having a reduced immunostimulatory effect, wherein the oligonucleotide comprises a 2'-5' internucleoside linkage at a position adjacent to, and on the 5' side of the CpG dinucleotide.

In a tenth aspect, the invention provides a method for increasing the immunostimulatory effect of a CpG-containing oligonucleotide. The method according to this aspect of the invention comprises introducing into the oligonucleotide a 3' substituted nucleoside at a position selected from the group consisting of 3rd nucleoside 5' to the CpG dinucleotide, 4th nucleoside 5' to the CpG dinucleotide, 5th nucleoside 5' to the CpG dinucleotide, 6th nucleoside 5' to the CpG dinucleotide, 2 nucleosides 3' to the CpG dinucleotide, 3rd nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 5th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 6th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, and combinations thereof. In certain preferred embodiments, the oligonucleotide is not an antisense oligonucleotide. In preferred embodiments, this method includes creating a 2'-5' linkage between the 2' position of a 3' substituted nucleoside and the 5' position of another nucleoside, which may or may not be a 3' substituted nucleoside.

In a eleventh aspect, the invention provides CpG-containing oligonucleotides having increased immunostimulatory effects, the oligonucleotide comprising a 3' substituted nucleoside at a position selected from the group consisting of 3rd nucleoside 5' to the CpG dinucleotide, 4th nucleoside 5' to the CpG dinucleotide, 5th nucleoside 5' to the CpG dinucleotide, 6th nucleoside 5' to the CpG dinucleotide, 2 nucleosides 3' to the CpG dinucleotide, 3rd nucleoside 3' to the CpG dinucleotide, 4th nucleoside

3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 5th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 6th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, and combinations thereof. In certain embodiments, the oligonucleotide is not an antisense oligonucleotide. . In preferred embodiments, CpG-containing oligonucleotides according to this aspect of the invention include a 2'-5' linkage between the 2' position of a 3' substituted nucleoside and the 5' position of another nucleoside, which may or may not be a 3' substituted nucleoside.

In an twelfth aspect, the invention provides a method for inducing an immune response in a mammal, the method comprising administering to the mammal an oligonucleotide comprising a 3'-substituted nucleoside at a position selected from the group consisting of 3rd nucleoside 5' to the CpG dinucleotide, 4th nucleoside 5' to the CpG dinucleotide, 5th nucleoside 5' to the CpG dinucleotide, 6th nucleoside 5' to the CpG dinucleotide, 2 nucleosides 3' to the CpG dinucleotide, 3rd nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 5th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 6th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, and combinations. In certain preferred embodiments, the oligonucleotide is not an antisense oligonucleotide. In preferred embodiments, CpG-containing oligonucleotides used in this aspect of the invention include a 2'-5' linkage between the 2' position of a 3' substituted nucleoside and the 5' position of another nucleoside, which may or may not be a 3' substituted nucleoside.

In a thirteenth aspect, the invention provides a method for increasing the immunostimulatory effect of a CpG-containing oligonucleotide. The method according to this aspect of the invention comprises introducing into the oligonucleotide an uncharged internucleoside linkage at a position selected from the group consisting of 3rd nucleoside 5' to the CpG



dinucleotide, 4th nucleoside 5' to the CpG dinucleotide, 5th nucleoside 5' to the CpG dinucleotide, 6th nucleoside 5' to the CpG dinucleotide, 2 nucleosides 3' to the CpG dinucleotide, 3rd nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 5th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 6th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, and combinations thereof. In certain preferred embodiments, the oligonucleotide is not an antisense oligonucleotide.

In a fourteenth aspect, the invention provides CpG-containing oligonucleotides having increased immunostimulatory effects, the oligonucleotide comprising an uncharged internucleoside at a position selected from the group consisting of 3rd nucleoside 5' to the CpG dinucleotide, 4th nucleoside 5' to the CpG dinucleotide, 5th nucleoside 5' to the CpG dinucleotide, 6th nucleoside 5' to the CpG dinucleotide, 2 nucleosides 3' to the CpG dinucleotide, 3rd nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 5th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 6th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, and combinations thereof.

In a fifteenth aspect, the invention provides a method for inducing an immune response in a mammal, the method comprising administering to the mammal an oligonucleotide comprising an uncharged internucleoside linkage at a position selected from the group consisting of 3rd nucleoside 5' to the CpG dinucleotide, 4th nucleoside 5' to the CpG dinucleotide, 5th nucleoside 5' to the CpG dinucleotide, 6th nucleoside 5' to the CpG dinucleotide, 2 nucleosides 3' to the CpG dinucleotide, 3rd nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 5th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 6th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to

the CpG dinucleotide, and combinations. In certain preferred embodiments, the oligonucleotide is not an antisense oligonucleotide.

In a sixteenth aspect, the invention provides a method for increasing the immunostimulatory effect of a CpG-containing oligonucleotide. The method according to this aspect of the invention comprises introducing into the oligonucleotide a 2'-5' internucleoside linkage at a position selected from the group consisting of 3rd nucleoside 5' to the CpG dinucleotide, 4th nucleoside 5' to the CpG dinucleotide, 5th nucleoside 5' to the CpG dinucleotide, 6th nucleoside 5' to the CpG dinucleotide, 2 nucleosides 3' to the CpG dinucleotide, 3rd nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 5th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 6th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, and combinations thereof. In certain preferred embodiments, the oligonucleotide is not an antisense oligonucleotide.

In a seventeenth aspect, the invention provides CpG-containing oligonucleotides having increased immunostimulatory effects, the oligonucleotide comprising a 2'-5' internucleoside linkage at a position selected from the group consisting of 3rd nucleoside 5' to the CpG dinucleotide, 4th nucleoside 5' to the CpG dinucleotide, 5th nucleoside 5' to the CpG dinucleotide, 6th nucleoside 5' to the CpG dinucleotide, 2 nucleosides 3' to the CpG dinucleotide, 3rd nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 5th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 6th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, and combinations thereof.

In an eighteenth aspect, the invention provides a method for inducing an immune response in a mammal, the method comprising administering to the mammal an oligonucleotide comprising a 2'-5' internucleoside linkage at a position selected from the group consisting of 3rd nucleoside 5' to the CpG

dinucleotide, 4th nucleoside 5' to the CpG dinucleotide, 5th nucleoside 5' to the CpG dinucleotide, 6th nucleoside 5' to the CpG dinucleotide, 2 nucleosides 3' to the CpG dinucleotide, 3rd nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 5th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 6th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, and combinations. In certain preferred embodiments, the oligonucleotide is not an antisense oligonucleotide.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

Figure 1 shows results of a proliferation assay of mouse spleen cells in the presence of no oligonucleotide (C), lipopolysaccharide (LPS), or various unsubstituted or 2' or 3' substituted oligonucleotides.

Figure 2 shows spleen enlargement in mice administered no oligonucleotide or various unsubstituted or 2' or 3' substituted oligonucleotides.

Figure 3 shows results of a proliferation assay of mouse spleen cells and shows spleen enlargement in mice administered no oligonucleotide (C), or various unsubstituted or methylphosphonate substituted oligonucleotides. Underlined nucleosides have a methylphosphonate linkage at the 3' position.

### **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

The invention relates to the therapeutic use of oligonucleotides, both in the antisense approach, and as immunostimulatory agents. The patents and publications cited herein reflect the level of knowledge in the field and are hereby incorporated by reference in their entirety. In the event of conflict between any teaching of any reference cited herein and the present specification, the latter shall prevail, for purposes of the invention.

The invention provides methods for modulating the immune response caused by CpG-containing oligonucleotides. The methods according to the invention enables both decreasing the immunostimulatory effect for antisense applications, as well as increasing the immunostimulatory effect for immunotherapy applications. Thus, the invention further provides oligonucleotides having optimal levels of immunostimulatory effect for either application and methods for making and using such oligonucleotides.

The present inventor has surprisingly discovered that positional modification of CpG-containing oligonucleotides dramatically affects their immunostimulatory capabilities. In particular, 3' alkylation or alkoxylation of oligonucleotides, or introduction of an uncharged internucleoside linkage, at particular positions 5' or 3' to the CpG dinucleotide either enhances or reduces their immunostimulatory effect in a reproducible and predictable manner.

As used for the first nine aspects of the invention, the term "complementary" means having the ability to hybridize to a genomic region, a gene, or an RNA transcript thereof under physiological conditions. Such hybridization is ordinarily the result of base-specific hydrogen bonding between complementary strands, preferably to form Watson-Crick or Hoogsteen base pairs, although other modes of hydrogen bonding, as well as base stacking can also lead to hybridization. As a practical matter, such hybridization can be inferred from the observation of specific gene expression inhibition.

As used for the first nine aspects of this invention, "antisense activity" means that the oligonucleotide, when introduced into a cell or an animal, causes a reduction in the expression of the gene to which it is complementary.

In a first aspect, the invention provides a method for reducing the immunostimulatory effect of a CpG-containing oligonucleotide. The method according to this aspect of the invention comprises introducing a 3' substituted nucleoside into the oligonucleotide at a position adjacent to, and on the 5' and/or 3' side of the CpG dinucleotide. In preferred embodiments, this method includes creating a 2'-5' linkage between the 2' position of a 3' substituted nucleoside and the 5' position of another nucleoside, which may or may not be a 3' substituted nucleoside.

The method according to this aspect of the invention can be conveniently carried out using any of the well-known synthesis techniques by simply using the appropriate 3' substituted monomer synthon in the synthesis process in the cycle immediately following the incorporation of the CpG dinucleotide. Preferred monomers include phosphoramidites, phosphotriesters and H-phosphonates. Thus, for purposes of the invention, "introducing a 3' substituted nucleoside into the oligonucleotide at a position adjacent to, and on the 5' side of the CpG dinucleotide" simply means synthesizing an oligonucleotide that has a 3' substituted nucleoside at such a position. Synthesis of oligonucleotides containing 3' substituted nucleosides has recently been described by Kumar and Takaku, *Bioorganic & Medicinal Chemistry Letters* 9: 2515-2520 (1999).

In a second aspect, the invention provides a CpG-containing oligonucleotide having a reduced immunostimulatory effect, wherein the oligonucleotide comprises a 3' substituted nucleoside at a position adjacent to, and on the 5' and/or 3' side of the CpG dinucleotide. In preferred embodiments, CpG-containing oligonucleotides according to this aspect of the invention include a 2'-5' linkage between the 2' position of a 3' substituted

nucleoside and the 5' position of another nucleoside, which may or may not be a 3' substituted nucleoside.

Preferably, such oligonucleotides will have from about 12 to about 50 nucleotides, most preferably from about 12 to about 35 nucleotides. Preferred oligonucleotides according to this aspect of the invention are complementary to a gene or gene transcript. More preferably, such oligonucleotides have antisense activity. In some preferred embodiments, the oligonucleotide has only one 3' substituted nucleoside for each CpG dinucleotide present in the oligonucleotide. In some preferred embodiments, the oligonucleotide has only one 3' substituted nucleoside.

In a third aspect, the invention provides a method for obtaining an antisense-specific reduction in the expression of a gene in a mammal, the method comprising administering to the mammal a CpG-containing oligonucleotide having a reduced immunostimulatory effect, wherein the oligonucleotide comprises a 3' substituted nucleoside at a position adjacent to, and on the 5' and/or 3' side of the CpG dinucleotide. In preferred embodiments, CpG-containing oligonucleotides used in this aspect of the invention include a 2'-5' linkage between the 2' position of a 3' substituted nucleoside and the 5' position of another nucleoside, which may or may not be a 3' substituted nucleoside.

In the methods according to this aspect of the invention, preferably, administration of oligonucleotides should be parenteral, oral, sublingual, transdermal, topical, intranasal or intrarectal. Administration of the therapeutic compositions can be carried out using known procedures at dosages and for periods of time effective to reduce symptoms or surrogate markers of the disease. When administered systemically, the therapeutic composition is preferably administered at a sufficient dosage to attain a blood level of oligonucleotide from about 0.01 micromolar to about 10 micromolar. For localized administration, much lower concentrations than this may be effective, and much higher concentrations may be tolerated. Preferably, a total dosage of oligonucleotide will range from about 0.1 mg oligonucleotide

per patient per day to about 200 mg oligonucleotide per kg body weight per day. It may be desirable to administer simultaneously, or sequentially a therapeutically effective amount of one or more of the therapeutic compositions of the invention to an individual as a single treatment episode. In a preferred embodiment, after the composition of matter is administered, one or more measurement is taken of biological effects selected from the group consisting of complement activation, mitogenesis and inhibition of thrombin clot formation.

The method according to this aspect of the invention is useful in animal models of disease or gene expression, and is further useful for the therapeutic treatment of human or animal disease.

In a fourth aspect, the invention provides a method for reducing the immunostimulatory effect of a CpG-containing oligonucleotide. The method according to this aspect of the invention comprises introducing an uncharged internucleoside linkage into the oligonucleotide at a position adjacent to, and on the 5' side of the CpG dinucleotide.

For purposes of the fourth, fifth and sixth aspects of the invention, preferred uncharged internucleoside linkages include, without limitation, phosphoramidate linkages, carbamate linkages, peptide linkages, alkylphosphonate linkages, particularly methylphosphonate linkages, and further include linkages in which the non-bridging oxygen atom of the phosphate is either covalently bonded to or substituted by a chemical moiety selected from halogen (preferably Cl, Br, or F), lower alkyl group containing 1-6 saturated or unsaturated carbon atoms, aryl or allyl group having 2-6 carbon atoms, wherein such alkyl, aryl or allyl group may be unsubstituted or may be substituted, e.g., with halo, hydroxy, trifluoromethyl, cyano, nitro, acyl, acyloxy, alkoxy, carboxyl, carbalkoxyl, or amino groups; and, an amino group.

The method according to this aspect of the invention can be conveniently carried out using any of the well-known synthesis techniques by simply using the appropriate P-substituted monomer synthon in the synthesis



process in the cycle immediately following the incorporation of the CpG dinucleotide. Preferred monomers include phosphites, phosphotriesters and H-phosphites. Thus, for purposes of the invention, "introducing an uncharged internucleoside linkage into the oligonucleotide at a position adjacent to, and on the 5' side of the CpG dinucleotide" simply means synthesizing an oligonucleotide that has an uncharged internucleoside nucleoside linkage at such a position, *i.e.*, the 5' position of the C of the CpG forms part of the uncharged linkage. Synthesis of oligonucleotides containing uncharged internucleoside linkages is well known in the art.

In a fifth aspect, the invention provides a CpG-containing oligonucleotide having a reduced immunostimulatory effect, wherein the oligonucleotide comprises an uncharged internucleoside linkage at a position adjacent to, and on the 5' side of the CpG dinucleotide. Preferably, such oligonucleotides will have from about 12 to about 50 nucleotides, most preferably from about 12 to about 35 nucleotides. Preferred oligonucleotides according to this aspect of the invention are complementary to a gene or gene transcript. More preferably, such oligonucleotides have antisense activity. In some preferred embodiments, the oligonucleotide has only one uncharged internucleoside linkage for each CpG dinucleotide present in the oligonucleotide. In some preferred embodiments, the oligonucleotide has only one an uncharged internucleoside linkage.

In a sixth aspect, the invention provides a method for obtaining an antisense-specific reduction in the expression of a gene in a mammal, the method comprising administering to the mammal a CpG-containing oligonucleotide having a reduced immunostimulatory effect, wherein the oligonucleotide comprises an uncharged internucleoside linkage at a position adjacent to, and on the 5' side of the CpG dinucleotide.

In the methods according to this aspect of the invention, preferably, administration of oligonucleotides should be parenteral, oral, sublingual, transdermal, topical, intranasal or intrarectal. Administration of the

therapeutic compositions can be carried out using known procedures at dosages and for periods of time effective to reduce symptoms or surrogate markers of the disease. When administered systemically, the therapeutic composition is preferably administered at a sufficient dosage to attain a blood level of oligonucleotide from about 0.01 micromolar to about 10 micromolar. For localized administration, much lower concentrations than this may be effective, and much higher concentrations may be tolerated. Preferably, a total dosage of oligonucleotide will range from about 0.1 mg oligonucleotide per patient per day to about 200 mg oligonucleotide per kg body weight per day. It may be desirable to administer simultaneously, or sequentially a therapeutically effective amount of one or more of the therapeutic compositions of the invention to an individual as a single treatment episode. In a preferred embodiment, after the composition of matter is administered, one or more measurement is taken of biological effects selected from the group consisting of complement activation, mitogenesis and inhibition of thrombin clot formation.

The method according to this aspect of the invention is useful in animal models of disease or gene expression, and is further useful for the therapeutic treatment of human or animal disease.

In a seventh aspect, the invention provides a method for reducing the immunostimulatory effect of a CpG-containing oligonucleotide. The method according to this aspect of the invention comprises introducing a 2'-5' internucleoside linkage into the oligonucleotide at a position adjacent to, and on the 5' side of the CpG dinucleotide.

The method according to this aspect of the invention can be conveniently carried out using any of the well-known synthesis techniques by simply using the appropriate 3'-protected monomer synthon in the synthesis process in the cycle immediately following the incorporation of the CpG dinucleotide. Preferred monomers include phosphoramidites, phosphotriesters and H-phosphonates. Thus, for purposes of the invention, "introducing a 2'-5' internucleoside linkage into the oligonucleotide at a

position adjacent to, and on the 5' side of the CpG dinucleotide" simply means synthesizing an oligonucleotide that has an uncharged internucleoside nucleoside linkage at such a position, *i.e.*, the 5' position of the C of the CpG forms part of the 2'-5' linkage. Synthesis of oligonucleotides containing 2'-5' internucleoside linkages is well known in the art.

In an eighth aspect, the invention provides a CpG-containing oligonucleotide having a reduced immunostimulatory effect, wherein the oligonucleotide comprises a 2'-5' internucleoside linkage at a position adjacent to, and on the 5' side of the CpG dinucleotide. Preferably, such oligonucleotides will have from about 12 to about 50 nucleotides, most preferably from about 12 to about 35 nucleotides. Preferred oligonucleotides according to this aspect of the invention are complementary to a gene or gene transcript. More preferably, such oligonucleotides have antisense activity. In some preferred embodiments, the oligonucleotide has only one 2'-5' internucleoside linkage for each CpG dinucleotide present in the oligonucleotide. In some preferred embodiments, the oligonucleotide has only one 2'-5' internucleoside linkage.

In a ninth aspect, the invention provides a method for obtaining an antisense-specific reduction in the expression of a gene in a mammal, the method comprising administering to the mammal a CpG-containing oligonucleotide having a reduced immunostimulatory effect, wherein the oligonucleotide comprises a 2'-5' internucleoside linkage at a position adjacent to, and on the 5' side of the CpG dinucleotide.

In the methods according to this aspect of the invention, preferably, administration of oligonucleotides should be parenteral, oral, sublingual, transdermal, topical, intranasal or intrarectal. Administration of the therapeutic compositions can be carried out using known procedures at dosages and for periods of time effective to reduce symptoms or surrogate markers of the disease. When administered systemically, the therapeutic composition is preferably administered at a sufficient dosage to attain a blood

level of oligonucleotide from about 0.01 micromolar to about 10 micromolar. For localized administration, much lower concentrations than this may be effective, and much higher concentrations may be tolerated. Preferably, a total dosage of oligonucleotide will range from about 0.1 mg oligonucleotide per patient per day to about 200 mg oligonucleotide per kg body weight per day. It may be desirable to administer simultaneously, or sequentially a therapeutically effective amount of one or more of the therapeutic compositions of the invention to an individual as a single treatment episode. In a preferred embodiment, after the composition of matter is administered, one or more measurement is taken of biological effects selected from the group consisting of complement activation, mitogenesis and inhibition of thrombin clot formation.

The method according to this aspect of the invention is useful in animal models of disease or gene expression, and is further useful for the therapeutic treatment of human or animal disease.

In a tenth aspect, the invention provides a method for increasing the immunostimulatory effect of a CpG-containing oligonucleotide. The method according to this aspect of the invention comprises introducing into the oligonucleotide a 3' substituted nucleoside at a position selected from the group consisting of 3rd nucleoside 5' to the CpG dinucleotide, 4th nucleoside 5' to the CpG dinucleotide, 5th nucleoside 5' to the CpG dinucleotide, 6th nucleoside 5' to the CpG dinucleotide, 2 nucleosides 3' to the CpG dinucleotide, 3rd nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 5th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 6th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, and combinations thereof. In certain preferred embodiments, the oligonucleotide is not an antisense oligonucleotide. In preferred embodiments, this method includes creating a 2'-5' linkage between the 2' position of a 3' substituted

nucleoside and the 5' position of another nucleoside, which may or may not be a 3' substituted nucleoside.

For purposes of the tenth aspect of the invention, an "antisense oligonucleotide" is an oligonucleotide that is exactly complementary to a gene or gene transcript, and capable of reducing the expression of the gene or gene transcript to which it is exactly complementary.

The method according to this aspect of the invention can be conveniently carried out using any of the well-known synthesis techniques by simply using the appropriate 3' substituted monomer synthon in the synthesis process in the cycle immediately following the incorporation of the CpG dinucleotide. Preferred monomers include phosphoramidites, phosphotriesters and H-phosphonates. Thus, for purposes of the invention, "introducing into the oligonucleotide a 3' substituted nucleoside at a position selected from the group consisting of 3rd nucleoside 5' to the CpG dinucleotide, 4th nucleoside 5' to the CpG dinucleotide, 5th nucleoside 5' to the CpG dinucleotide, 6th nucleoside 5' to the CpG dinucleotide, 2 nucleosides 3' to the CpG dinucleotide, 3rd nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 5th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 6th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, and combinations thereof" simply means synthesizing an oligonucleotide that has a 3' substituted nucleoside at such a position or positions. .

In a eleventh aspect, the invention provides CpG-containing oligonucleotides having increased immunostimulatory effects, the oligonucleotide comprising a 3' substituted nucleoside at a position selected from the group consisting of 3rd nucleoside 5' to the CpG dinucleotide, 4th nucleoside 5' to the CpG dinucleotide, 5th nucleoside 5' to the CpG dinucleotide, 6th nucleoside 5' to the CpG dinucleotide, 2 nucleosides 3' to the CpG dinucleotide, 3rd nucleoside 3' to the CpG dinucleotide, 4th nucleoside

3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 5th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 6th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, and combinations thereof. In certain embodiments, the oligonucleotide is not an antisense oligonucleotide. . In preferred embodiments, CpG-containing oligonucleotides according to this aspect of the invention include a 2'-5' linkage between the 2' position of a 3' substituted nucleoside and the 5' position of another nucleoside, which may or may not be a 3' substituted nucleoside.

Preferred oligonucleotides according to the fourteenth aspect of the invention are from about 6 to about 50 nucleotides in length, and may further comprise modified internucleotide linkages or modified sugars to improve stability, bioavailability, or other clinically relevant features.

In a twelfth aspect, the invention provides a method for inducing an immune response in a mammal, the method comprising administering to the mammal an oligonucleotide comprising a 3'-substituted nucleoside at a position selected from the group consisting of 3rd nucleoside 5' to the CpG dinucleotide, 4th nucleoside 5' to the CpG dinucleotide, 5th nucleoside 5' to the CpG dinucleotide, 6th nucleoside 5' to the CpG dinucleotide, 2 nucleosides 3' to the CpG dinucleotide, 3rd nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 5th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 6th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, and combinations. In certain preferred embodiments, the oligonucleotide is not an antisense oligonucleotide. In preferred embodiments, CpG-containing oligonucleotides used in this aspect of the invention include a 2'-5' linkage between the 2' position of a 3' substituted nucleoside and the 5' position of another nucleoside, which may or may not be a 3' substituted nucleoside.

In the methods according to this aspect of the invention, preferably, administration of oligonucleotides should be parenteral, oral, sublingual, transdermal, topical, intranasal or intrarectal. Administration of the therapeutic compositions can be carried out using known procedures at dosages and for periods of time effective to reduce symptoms or surrogate markers of the disease. When administered systemically, the therapeutic composition is preferably administered at a sufficient dosage to attain a blood level of oligonucleotide from about 0.01 micromolar to about 10 micromolar. For localized administration, much lower concentrations than this may be effective, and much higher concentrations may be tolerated. Preferably, a total dosage of oligonucleotide will range from about 0.1 mg oligonucleotide per patient per day to about 200 mg oligonucleotide per kg body weight per day. It may be desirable to administer simultaneously, or sequentially a therapeutically effective amount of one or more of the therapeutic compositions of the invention to an individual as a single treatment episode. In a preferred embodiment, after the composition of matter is administered, one or more measurement is taken of biological effects selected from the group consisting of complement activation, mitogenesis and inhibition of thrombin clot formation.

In certain preferred embodiments, oligonucleotides according to the invention are administered in combination with vaccines and/or adjuvants to enhance the specificity or magnitude of the immune response. Either the oligonucleotide or the vaccine, or both may optionally be linked to an immunogenic protein, such as keyhole limpet hemocyanin, cholera toxin B subunit, or any other immunogenic carrier protein. Any of the plethora of adjuvants may be used, including, without limitation, Freund's complete adjuvant. For purposes of this aspect "in combination with" means in the course of treating the same disease in the same patient, and includes administering the oligonucleotide and/or the vaccine and/or the adjuvant in any order, including simultaneous administration, as well as temporally spaced order of up to several days apart. Such combination treatment may also include more than a single administration of the oligonucleotide, and/or

independently the vaccine, and/or independently the adjuvant. The administration of the oligonucleotide and/or vaccine and/or adjuvant may be by the same or different routes.

The method according to this aspect of the invention is useful for model studies of the immune system, and is further useful for the therapeutic treatment of human or animal disease.

In a thirteenth aspect, the invention provides a method for increasing the immunostimulatory effect of a CpG-containing oligonucleotide. The method according to this aspect of the invention comprises introducing into the oligonucleotide an uncharged internucleoside linkage at a position selected from the group consisting of 3rd nucleoside 5' to the CpG dinucleotide, 4th nucleoside 5' to the CpG dinucleotide, 5th nucleoside 5' to the CpG dinucleotide, 6th nucleoside 5' to the CpG dinucleotide, 2 nucleosides 3' to the CpG dinucleotide, 3rd nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 5th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 6th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, and combinations thereof. In certain preferred embodiments, the oligonucleotide is not an antisense oligonucleotide.

For purposes of the thirteenth, fourteenth and fifteenth aspects of the invention, preferred uncharged internucleoside linkages include, without limitation, phosphoramidate linkages, carbamate linkages, peptide linkages, alkylphosphonate linkages, particularly methylphosphonate linkages, and further include linkages in which the non-bridging oxygen atom of the phosphate is either covalently bonded to or substituted by a chemical moiety selected from halogen (preferably Cl, Br, or F), lower alkyl group containing 1-6 saturated or unsaturated carbon atoms, aryl or allyl group having 2-6 carbon atoms, wherein such alkyl, aryl or allyl group may be unsubstituted or may be substituted, e.g., with halo, hydroxy, trifluoromethyl, cyano, nitro,



acyl, acyloxy, alkoxy, carboxyl, carbalkoxyl, or amino groups; and, an amino group.

The method according to this aspect of the invention can be conveniently carried out using any of the well-known synthesis techniques by simply using the appropriate P-substituted monomer synthon in the synthesis process in the cycle immediately following the incorporation of the CpG dinucleotide. Preferred monomers include phosphites, phosphotriesters and H-phosphites. Thus, for purposes of the invention, "introducing into the oligonucleotide an uncharged internucleoside linkage at a position" simply means synthesizing an oligonucleotide that has an uncharged internucleoside nucleoside linkage at such a position, *i.e.*, counting from the C of the CpG, the uncharged internucleoside linkage is the 3' linkage of that nucleoside. Synthesis of oligonucleotides containing uncharged internucleoside linkages is well known in the art.

In a fourteenth aspect, the invention provides CpG-containing oligonucleotides having increased immunostimulatory effects, the oligonucleotide comprising an uncharged internucleoside at a position selected from the group consisting of 3rd nucleoside 5' to the CpG dinucleotide, 4th nucleoside 5' to the CpG dinucleotide, 5th nucleoside 5' to the CpG dinucleotide, 6th nucleoside 5' to the CpG dinucleotide, 2 nucleosides 3' to the CpG dinucleotide, 3rd nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 5th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 6th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, and combinations thereof. Preferred oligonucleotides according to this aspect of the invention are complementary to a gene or gene transcript. More preferably, such oligonucleotides have antisense activity. In some preferred embodiments, the oligonucleotide has only one uncharged internucleoside linkage for each CpG dinucleotide present in the

oligonucleotide. In some preferred embodiments, the oligonucleotide has only one an uncharged internucleoside linkage.

Preferred oligonucleotides according to the fourteenth aspect of the invention are from about 6 to about 50 nucleotides in length, and may further comprise modified internucleotide linkages or modified sugars to improve stability, bioavailability, or other clinically relevant features.

In a fifteenth aspect, the invention provides a method for inducing an immune response in a mammal, the method comprising administering to the mammal an oligonucleotide comprising an uncharged internucleoside linkage at a position selected from the group consisting of 3rd nucleoside 5' to the CpG dinucleotide, 4th nucleoside 5' to the CpG dinucleotide, 5th nucleoside 5' to the CpG dinucleotide, 6th nucleoside 5' to the CpG dinucleotide, 2 nucleosides 3' to the CpG dinucleotide, 3rd nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 5th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 6th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, and combinations. In certain preferred embodiments, the oligonucleotide is not an antisense oligonucleotide.

In the methods according to this aspect of the invention, preferably, administration of oligonucleotides should be parenteral, oral, sublingual, transdermal, topical, intranasal or intrarectal. Administration of the therapeutic compositions can be carried out using known procedures at dosages and for periods of time effective to reduce symptoms or surrogate markers of the disease. When administered systemically, the therapeutic composition is preferably administered at a sufficient dosage to attain a blood level of oligonucleotide from about 0.01 micromolar to about 10 micromolar. For localized administration, much lower concentrations than this may be effective, and much higher concentrations may be tolerated. Preferably, a total dosage of oligonucleotide will range from about 0.1 mg oligonucleotide per patient per day to about 200 mg oligonucleotide per kg body weight per

day. It may be desirable to administer simultaneously, or sequentially a therapeutically effective amount of one or more of the therapeutic compositions of the invention to an individual as a single treatment episode. In a preferred embodiment, after the composition of matter is administered, one or more measurement is taken of biological effects selected from the group consisting of complement activation, mitogenesis and inhibition of thrombin clot formation.

In certain preferred embodiments, oligonucleotides according to the invention are administered in combination with vaccines and/or adjuvants to enhance the specificity or magnitude of the immune response. Either the oligonucleotide or the vaccine, or both may optionally be linked to an immunogenic protein, such as keyhole limpet hemocyanin, cholera toxin B subunit, or any other immunogenic carrier protein. Any of the plethora of adjuvants may be used, including, without limitation, Freund's complete adjuvant. For purposes of this aspect "in combination with" means in the course of treating the same disease in the same patient, and includes administering the oligonucleotide and/or the vaccine and/or the adjuvant in any order, including simultaneous administration, as well as temporally spaced order of up to several days apart. Such combination treatment may also include more than a single administration of the oligonucleotide, and/or independently the vaccine, and/or independently the adjuvant. The administration of the oligonucleotide and/or vaccine and/or adjuvant may be by the same or different routes.

In a sixteenth aspect, the invention provides a method for increasing the immunostimulatory effect of a CpG-containing oligonucleotide. The method according to this aspect of the invention comprises introducing into the oligonucleotide a 2'-5' internucleoside linkage at a position selected from the group consisting of 3rd nucleoside 5' to the CpG dinucleotide, 4th nucleoside 5' to the CpG dinucleotide, 5th nucleoside 5' to the CpG dinucleotide, 6th nucleoside 5' to the CpG dinucleotide, 2 nucleosides 3' to the CpG dinucleotide, 3rd nucleoside 3' to the CpG dinucleotide, 4th nucleoside

3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 5th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 6th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, and combinations thereof. In certain preferred embodiments, the oligonucleotide is not an antisense oligonucleotide.

The method according to this aspect of the invention can be conveniently carried out using any of the well-known synthesis techniques by simply using the appropriate 3'-protected monomer synthon in the synthesis process in the cycle immediately following the incorporation of the CpG dinucleotide. Preferred monomers include phosphoramidites, phosphotriesters and H-phosphonates. Thus, for purposes of the invention, "introducing into the oligonucleotide a 2'-5' internucleoside linkage at a position" simply means synthesizing an oligonucleotide that has a 2'-5' internucleoside nucleoside linkage at such a position, *i.e.*, counting from the C of the CpG, the uncharged internucleoside linkage is the 3' linkage of that nucleoside. Synthesis of oligonucleotides containing 2'-5' internucleoside linkages is well known in the art.

In a seventeenth aspect, the invention provides CpG-containing oligonucleotides having increased immunostimulatory effects, the oligonucleotide comprising a 2'-5' internucleoside linkage at a position selected from the group consisting of 3rd nucleoside 5' to the CpG dinucleotide, 4th nucleoside 5' to the CpG dinucleotide, 5th nucleoside 5' to the CpG dinucleotide, 6th nucleoside 5' to the CpG dinucleotide, 2 nucleosides 3' to the CpG dinucleotide, 3rd nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 5th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 6th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, and combinations thereof.

Preferred oligonucleotides according to the seventeenth aspect of the invention are from about 6 to about 50 nucleotides in length, and may further comprise modified internucleotide linkages or modified sugars to improve stability, bioavailability, or other clinically relevant features.

In an eighteenth aspect, the invention provides a method for inducing an immune response in a mammal, the method comprising administering to the mammal an oligonucleotide comprising a 2'-5' internucleoside linkage at a position selected from the group consisting of 3rd nucleoside 5' to the CpG dinucleotide, 4th nucleoside 5' to the CpG dinucleotide, 5th nucleoside 5' to the CpG dinucleotide, 6th nucleoside 5' to the CpG dinucleotide, 2 nucleosides 3' to the CpG dinucleotide, 3rd nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 5th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 6th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, and combinations. In certain preferred embodiments, the oligonucleotide is not an antisense oligonucleotide.

In the methods according to this aspect of the invention, preferably, administration of oligonucleotides should be parenteral, oral, sublingual, transdermal, topical, intranasal or intrarectal. Administration of the therapeutic compositions can be carried out using known procedures at dosages and for periods of time effective to reduce symptoms or surrogate markers of the disease. When administered systemically, the therapeutic composition is preferably administered at a sufficient dosage to attain a blood level of oligonucleotide from about 0.01 micromolar to about 10 micromolar. For localized administration, much lower concentrations than this may be effective, and much higher concentrations may be tolerated. Preferably, a total dosage of oligonucleotide will range from about 0.1 mg oligonucleotide per patient per day to about 200 mg oligonucleotide per kg body weight per day. It may be desirable to administer simultaneously, or sequentially a therapeutically effective amount of one or more of the therapeutic

compositions of the invention to an individual as a single treatment episode. In a preferred embodiment, after the composition of matter is administered, one or more measurement is taken of biological effects selected from the group consisting of complement activation, mitogenesis and inhibition of thrombin clot formation.

In certain preferred embodiments, oligonucleotides according to the invention are administered in combination with vaccines and/or adjuvants to enhance the specificity or magnitude of the immune response. Either the oligonucleotide or the vaccine, or both may optionally be linked to an immunogenic protein, such as keyhole limpet hemocyanin, cholera toxin B subunit, or any other immunogenic carrier protein. Any of the plethora of adjuvants may be used, including, without limitation, Freund's complete adjuvant. For purposes of this aspect "in combination with" means in the course of treating the same disease in the same patient, and includes administering the oligonucleotide and/or the vaccine and/or the adjuvant in any order, including simultaneous administration, as well as temporally spaced order of up to several days apart. Such combination treatment may also include more than a single administration of the oligonucleotide, and/or independently the vaccine, and/or independently the adjuvant. The administration of the oligonucleotide and/or vaccine and/or adjuvant may be by the same or different routes.

For purposes of all aspects of the invention, the term "oligonucleotide" includes polymers of two or more deoxyribonucleotides, or any modified nucleoside, including 2'-halo-nucleosides, 2' or 3' substituted, 2' or 3'-O-substituted ribonucleosides, deazanucleosides or any combination thereof. Such monomers may be coupled to each other by any of the numerous known internucleoside linkages. In certain preferred embodiments, these internucleoside linkages may be phosphodiester, phosphotriester, phosphorothioate, or phosphoramidate linkages, 2'-5' linkages of any of the foregoing, or combinations thereof. The term oligonucleotide also encompasses such polymers having chemically modified bases or sugars

and/or having additional substituents, including without limitation lipophilic groups, intercalating agents, diamines and adamantane. The term oligonucleotide also encompasses PNA, LNA and oligonucleotides comprising non-pentose sugar (e.g. hexose) backbones or backbone sections. For purposes of the invention the term "3'-O-substituted" means substitution of the 3' position of the pentose moiety with a halogen (preferably Cl, Br, or F), or an -O-lower alkyl group containing 1-6 saturated or unsaturated carbon atoms, or with an -O-aryl or allyl group having 2-6 carbon atoms, wherein such alkyl, aryl or allyl group may be unsubstituted or may be substituted, e.g., with halo, hydroxy, trifluoromethyl, cyano, nitro, acyl, acyloxy, alkoxy, carboxyl, carbalkoxyl, or amino groups; or such 3' substitution may be with a hydroxy group (to produce a ribonucleoside), an amino or a halo group. For purposes of all aspects of the invention, the terms "CpG" or "CpG dinucleotide" means the dinucleotide 5'-cytidine-guanidine-3', wherein p is an internucleotide linkage, and wherein the sugar backbone of the dinucleotide may be ribose, deoxyribose, or 3' substituted ribose, or combinations thereof. In preferred embodiments of the first three aspects of the invention, p is selected from phosphodiester, phosphorothioate, alkylphosphonate, phosphotriester, stereospecific (Rp or Sp) phosphorothioate or alkylphosphonate, and 2'-5' covalent linkages of any of the above. The non-phosphodiester, non-phosphorothioate embodiments will further reduce immunostimulatory effects. In preferred embodiments of the last three aspects of the invention, p is selected from phosphodiester, phosphorothioate and phosphordithioate.

The following examples are intended to further illustrate certain preferred embodiments of the invention, and are not intended to limit the scope of the invention.

#### Example 1

##### Preparation of oligonucleotides containing site-specific 3'-O-methylribonucleosides

Oligonucleotides were synthesized using solid phase (1  $\mu$ mole scale) phosphoramidite chemistry on an automated DNA synthesizer (Expedite 8909, PE Biosystems, MA). The segment of 3'-O-methylribonucleoside phosphorothioate was incorporated into the oligonucleotide using 3'-O-methyl-2'-cyanoethyl ribonucleoside phosphoramidites (ChemGenes, MA). Oligonucleotide was sulfurized using 3H-1,2-benzodithiole-3-one-1,1-dioxide. Oligonucleotides were purified by preparative reversed-phase HPLC and characterized by CGE (data process through PE Nelson Turbochrom software) and MALDI-TOF mass analysis (Bruker Profelx III mass spectrometer).

#### Example 2

##### Modulation of immunostimulatory effect in vitro: 3' substitutions

To evaluate the immunostimulatory activity of oligonucleotides in the present study, we have used a mouse spleen cell proliferation assay, as described in Example 1. The oligos shown in Table 1 were used for these studies.

Table 1

Oligo No.	Sequence and Modification
1	TCCATGACGTT <b>C</b> CTGATGC
2	TCCATGACGTT <b>C</b> CTGATGC
3	TCCAUGACGTT <b>C</b> CTGATGC
4	TCCATGACGTT <b>C</b> CTGATGC
5	TCCATGACG <b>U</b> TCCTGATGC
Bold lettering indicates 3'-O-methyl modification	

We used a PS-oligonucleotide containing a single CpG dinucleotide (Oligo 1) and Oligos 2-5 in which substitution of one or two deoxynucleosides was carried out with modified nucleosides at specific sites.



Substitution with 3'-O-methyl ribonucleosides in Oligos 2-5 simultaneously led to incorporation of 2'-5' internucleoside linkages. Substitution 5' of the CpG with no intervening nucleosides (Oligo 2) diminished immunostimulatory activity. Surprisingly, substitution 3' of the CpG with no intervening nucleosides (Oligo 5) also diminished immunostimulatory activity. In addition, Oligos 3 and 4, with 3'-O-methylribonucleoside substitution 3' to the CpG increase immunostimulatory activity (indices of 4.6 +/- 0.43 and 5.7 +/- 0.87, respectively).

### Example 3

#### Modulation of immunostimulatory effect

#### in vivo: methylphosphonate substitutions

To test the applicability of the *in vitro* results to an *in vivo* model, selected oligonucleotides were administered to mice and the degree of splenomegaly was measured as an indicator of the level of immunostimulatory activity. A single dose of 5 mg/kg was administered to Balb/c mice (female, 4-6 weeks old, Harlan Sprague Dawley Inc) intraperitoneally. The mice were sacrificed 72 hours after administration and spleens were harvested and weighed. Positive control Oligo 1 caused a 74% increase in spleen weight compared to negative control mice receiving only PBS.

Oligonucleotides containing methylphosphonate internucleotide linkages are shown in Figure 3. Oligonucleotides were prepared having methylphosphonate linkages 3 or 4 nucleotides 5' to the CpG dinucleotide, or 2 or 3 nucleotides 3' to the CpG dinucleotide. As shown in Figure 3, all of these oligonucleotides were more immunostimulatory than Oligo 1 in both the mouse spleen cell proliferation assay and the spleen enlargement assay.

What is claimed is:

1. A method for reducing the immunostimulatory effect of a CpG-containing oligonucleotide, the method comprising introducing a 3' substituted nucleoside into the oligonucleotide at a position adjacent to, and on the 5' side of the CpG dinucleotide.
2. The method according to claim 1, wherein the method is used to make an oligonucleotide that is complementary to a gene or gene transcript.
3. The method according to claim 2, wherein the oligonucleotide has antisense activity.
4. The method according to claim 1, wherein only one 3' substituted nucleoside is introduced into the oligonucleotide for each CpG dinucleotide present in the oligonucleotide.
5. The method according to claim 1, wherein only one 3' substituted nucleoside is introduced into the oligonucleotide.
6. A CpG-containing oligonucleotide having a reduced immunostimulatory effect, wherein the oligonucleotide comprises a 3' substituted nucleoside at a position adjacent to, and on the 5' side of the CpG dinucleotide.
7. The oligonucleotide according to claim 6, wherein the oligonucleotide is from about 12 to about 50 nucleotides in length.
8. The oligonucleotide according to claim 7, wherein the oligonucleotide is from about 17 to about 35 nucleotides in length.

9. The oligonucleotide according to claim 6, wherein oligonucleotide is complementary to a gene or gene transcript.
10. The oligonucleotide according to claim 9, wherein oligonucleotide has antisense activity.
11. The oligonucleotide according to claim 6, wherein the oligonucleotide has only one 3' substituted nucleoside for each CpG dinucleotide present in the oligonucleotide.
12. The oligonucleotide according to claim 6, wherein the oligonucleotide has only one 3' substituted nucleoside.
13. A method for obtaining an antisense-specific reduction in the expression of a gene in a mammal, the method comprising administering to the mammal a CpG-containing oligonucleotide having a reduced immunostimulatory effect, wherein the oligonucleotide comprises a 3' substituted nucleoside at a position adjacent to, and on the 5' side of the CpG dinucleotide.
14. The method according to claim 13, wherein the oligonucleotide has only one 3' substituted nucleoside for each CpG dinucleotide present in the oligonucleotide.
15. The method according to claim 13, wherein the oligonucleotide has only one 3' substituted nucleoside.
16. A method for increasing the immunostimulatory effect of a CpG-containing oligonucleotide, the method comprising introducing into the oligonucleotide a 3' substituted nucleoside at a position selected from the group consisting of 3rd nucleoside 5' to the CpG dinucleotide, 4th nucleoside 5' to the CpG dinucleotide, 5th nucleoside 5' to the CpG dinucleotide, 6th

nucleoside 5' to the CpG dinucleotide, 2 nucleosides 3' to the CpG dinucleotide, 3rd nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 5th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 6th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, and combinations thereof.

17. The method according to claim 16, wherein the oligonucleotide is not an antisense oligonucleotide.

18. A CpG-containing oligonucleotide having increased immunostimulatory effects, the oligonucleotide comprising a 3' substituted nucleoside at a position selected from the group consisting of 3rd nucleoside 5' to the CpG dinucleotide, 4th nucleoside 5' to the CpG dinucleotide, 5th nucleoside 5' to the CpG dinucleotide, 6th nucleoside 5' to the CpG dinucleotide, 2 nucleosides 3' to the CpG dinucleotide, 3rd nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 5th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 6th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, and combinations thereof.

19. The oligonucleotide according to claim 18, wherein the oligonucleotide is not an antisense oligonucleotide.

20. The oligonucleotide according to claim 18, wherein the oligonucleotide is from about 6 to about 50 nucleotides in length.

21. The oligonucleotide according to claim 18, wherein the oligonucleotide further comprise modified internucleotide linkages or modified sugars to improve stability.

22. A method for inducing an immune response in a mammal, the method comprising administering to the mammal an oligonucleotide comprising a 3' substituted nucleoside at a position selected from the group consisting of 3rd nucleoside 5' to the CpG dinucleotide, 4th nucleoside 5' to the CpG dinucleotide, 5th nucleoside 5' to the CpG dinucleotide, 6th nucleoside 5' to the CpG dinucleotide, 2 nucleosides 3' to the CpG dinucleotide, 3rd nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 5th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 6th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, and combinations thereof.

23. The method according to claim 22, wherein the oligonucleotide is not an antisense oligonucleotide.

24. A method for increasing the immunostimulatory effect of a CpG-containing oligonucleotide, the method comprising introducing into the oligonucleotide an uncharged internucleoside linkage at a position selected from the group consisting of 3rd nucleoside 5' to the CpG dinucleotide, 4th nucleoside 5' to the CpG dinucleotide, 5th nucleoside 5' to the CpG dinucleotide, 6th nucleoside 5' to the CpG dinucleotide, 2 nucleosides 3' to the CpG dinucleotide, 3rd nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 5th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 6th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, and combinations thereof.

25. The method according to claim 24, wherein the uncharged internucleoside linkage is an alkylphosphonate.

26. The method according to claim 25, wherein the alkylphosphonate is a methylphosphonate.

27. The method according to claim 24, wherein the oligonucleotide is not an antisense oligonucleotide.

28. A CpG-containing oligonucleotide having increased immunostimulatory effects, the oligonucleotide comprising an uncharged internucleoside linkage at a position selected from the group consisting of 3rd nucleoside 5' to the CpG dinucleotide, 4th nucleoside 5' to the CpG dinucleotide, 5th nucleoside 5' to the CpG dinucleotide, 6th nucleoside 5' to the CpG dinucleotide, 2 nucleosides 3' to the CpG dinucleotide, 3rd nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 5th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 6th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, and combinations thereof.

29. The oligonucleotide according to claim 28, wherein the uncharged internucleoside linkage is an alkylphosphonate.

30. The oligonucleotide according to claim 29, wherein the alkylphosphonate is a methylphosphonate.

31. The oligonucleotide according to claim 28, wherein the oligonucleotide is not an antisense oligonucleotide.

32. The oligonucleotide according to claim 28, wherein the oligonucleotide is from about 6 to about 50 nucleotides in length.

33. The oligonucleotide according to claim 28, wherein the oligonucleotide further comprise modified internucleotide linkages or modified sugars to improve stability.

34. A method for inducing an immune response in a mammal, the method comprising administering to the mammal an oligonucleotide comprising an uncharged internucleoside linkage at a position selected from the group consisting of 3rd nucleoside 5' to the CpG dinucleotide, 4th nucleoside 5' to the CpG dinucleotide, 5th nucleoside 5' to the CpG dinucleotide, 6th nucleoside 5' to the CpG dinucleotide, 2 nucleosides 3' to the CpG dinucleotide, 3rd nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 5th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 6th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, and combinations thereof.

35. The method according to claim 34, wherein the uncharged internucleoside linkage is an alkylphosphonate.

36. The method according to claim 35, wherein the alkylphosphonate is a methylphosphonate.

37. The method according to claim 34, wherein the oligonucleotide is not an antisense oligonucleotide.

38. A method for reducing the immunostimulatory effect of a CpG-containing oligonucleotide, the method comprising introducing a 2'-5' internucleoside linkage into the oligonucleotide at a position adjacent to, and on the 5' side of the CpG dinucleotide.

39. The method according to claim 38, wherein the method is used to make an oligonucleotide that is complementary to a gene or gene transcript.

40. The method according to claim 39, wherein the oligonucleotide has antisense activity.

41. The method according to claim 38, wherein only one 2'-5' internucleoside linkage is introduced into the oligonucleotide for each CpG dinucleotide present in the oligonucleotide.

42. The method according to claim 38, wherein only one 2'-5' internucleoside linkage is introduced into the oligonucleotide.

43. A CpG-containing oligonucleotide having a reduced immunostimulatory effect, wherein the oligonucleotide comprises a 2'-5' internucleoside linkage at a position adjacent to, and on the 5' side of the CpG dinucleotide.

44. The oligonucleotide according to claim 43, wherein the oligonucleotide is from about 12 to about 50 nucleotides in length.

45. The oligonucleotide according to claim 44, wherein the oligonucleotide is from about 17 to about 35 nucleotides in length.

46. The oligonucleotide according to claim 43, wherein oligonucleotide is complementary to a gene or gene transcript.

47. The oligonucleotide according to claim 46, wherein oligonucleotide has antisense activity.



48. The oligonucleotide according to claim 43, wherein the oligonucleotide has only one 2'-5' internucleoside linkage for each CpG dinucleotide present in the oligonucleotide.

49. The oligonucleotide according to claim 43, wherein the oligonucleotide has only one 3' substituted nucleoside.

50. A method for obtaining an antisense-specific reduction in the expression of a gene in a mammal, the method comprising administering to the mammal a CpG-containing oligonucleotide having a reduced immunostimulatory effect, wherein the oligonucleotide comprises a 2'-5' internucleoside linkage at a position adjacent to, and on the 5' side of the CpG dinucleotide.

51. The method according to claim 50, wherein the oligonucleotide has only one 2'-5' internucleoside linkage for each CpG dinucleotide present in the oligonucleotide.

52. The method according to claim 50, wherein the oligonucleotide has only one 2'-5' internucleoside linkage.

53. A method for increasing the immunostimulatory effect of a CpG-containing oligonucleotide, the method comprising introducing into the oligonucleotide a 2'-5' internucleoside linkage at a position selected from the group consisting of 3rd nucleoside 5' to the CpG dinucleotide, 4th nucleoside 5' to the CpG dinucleotide, 5th nucleoside 5' to the CpG dinucleotide, 6th nucleoside 5' to the CpG dinucleotide, 2 nucleosides 3' to the CpG dinucleotide, 3rd nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 5th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 6th nucleoside 3' to

the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, and combinations thereof.

54. The method according to claim 53, wherein the 2'-5' internucleoside linkage is an alkylphosphonate.

55. A CpG-containing oligonucleotide having increased immunostimulatory effects, the oligonucleotide comprising a 2'-5' internucleoside linkage at a position selected from the group consisting of 3rd nucleoside 5' to the CpG dinucleotide, 4th nucleoside 5' to the CpG dinucleotide, 5th nucleoside 5' to the CpG dinucleotide, 6th nucleoside 5' to the CpG dinucleotide, 2 nucleosides 3' to the CpG dinucleotide, 3rd nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 5th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 6th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, and combinations thereof.

56. The oligonucleotide according to claim 55, wherein the oligonucleotide is not an antisense oligonucleotide.

57. The oligonucleotide according to claim 55, wherein the oligonucleotide is from about 6 to about 50 nucleotides in length.

58. The oligonucleotide according to claim 55, wherein the oligonucleotide further comprise modified internucleotide linkages or modified sugars to improve stability.

59. A method for inducing an immune response in a mammal, the method comprising administering to the mammal an oligonucleotide comprising a 2'-5' internucleoside linkage at a position selected from the

group consisting of 3rd nucleoside 5' to the CpG dinucleotide, 4th nucleoside 5' to the CpG dinucleotide, 5th nucleoside 5' to the CpG dinucleotide, 6th nucleoside 5' to the CpG dinucleotide, 2 nucleosides 3' to the CpG dinucleotide, 3rd nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 5th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, 6th nucleoside 3' to the CpG dinucleotide, 4th nucleoside 3' to the CpG dinucleotide, and combinations thereof.

60. The method according to claim 59, wherein the oligonucleotide is not an antisense oligonucleotide.

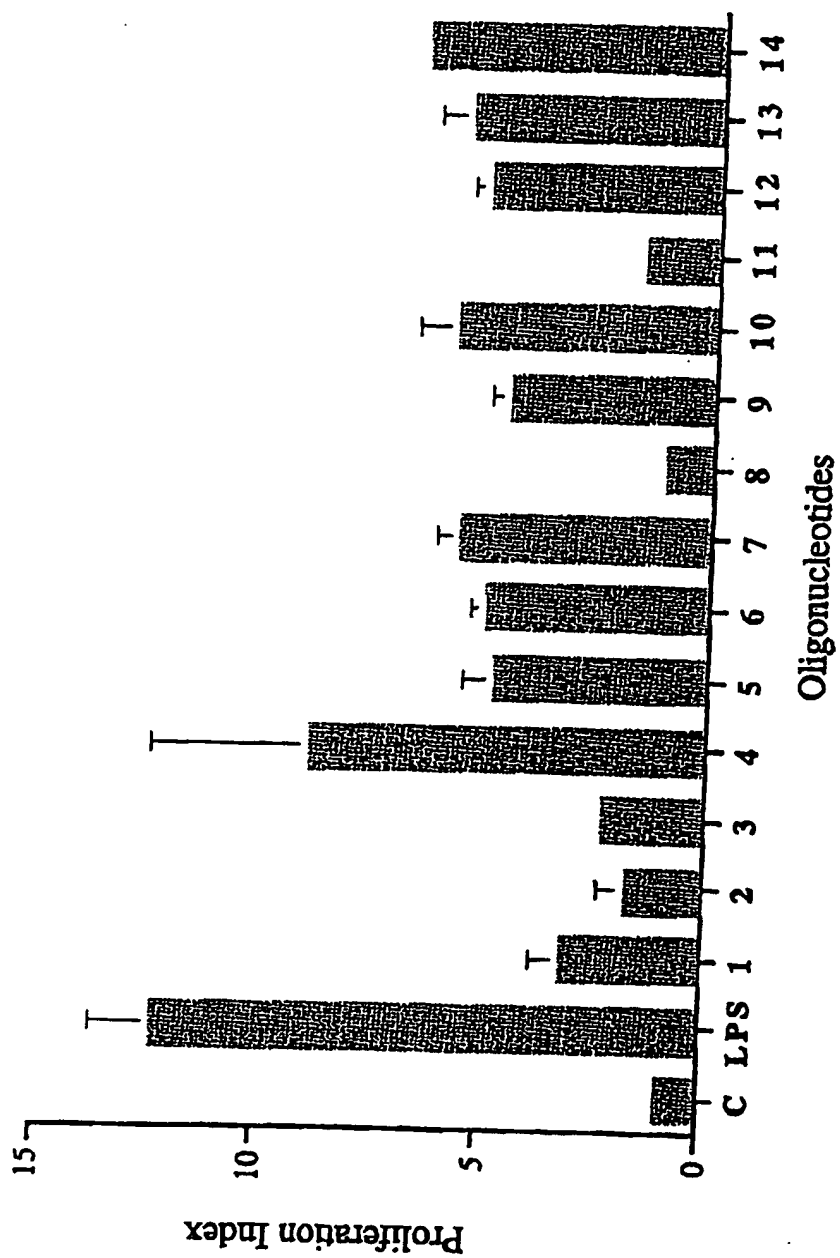


FIGURE 1

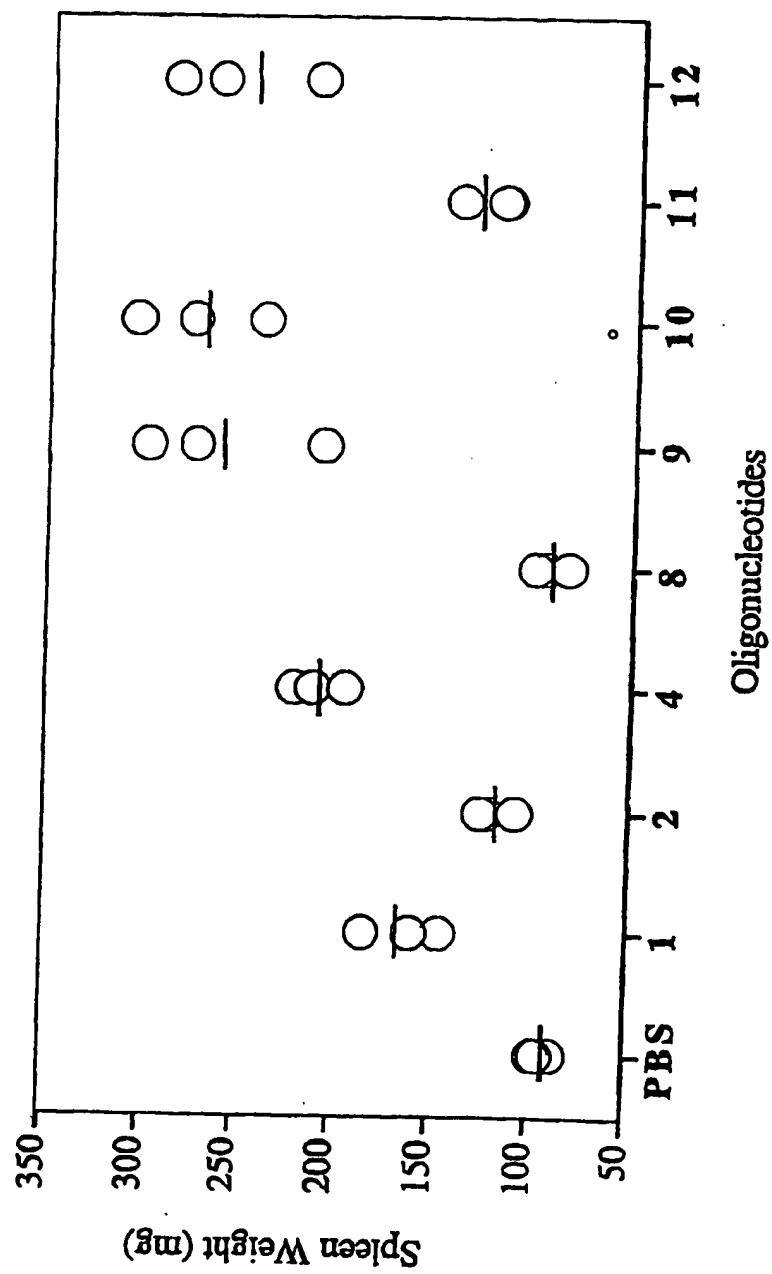
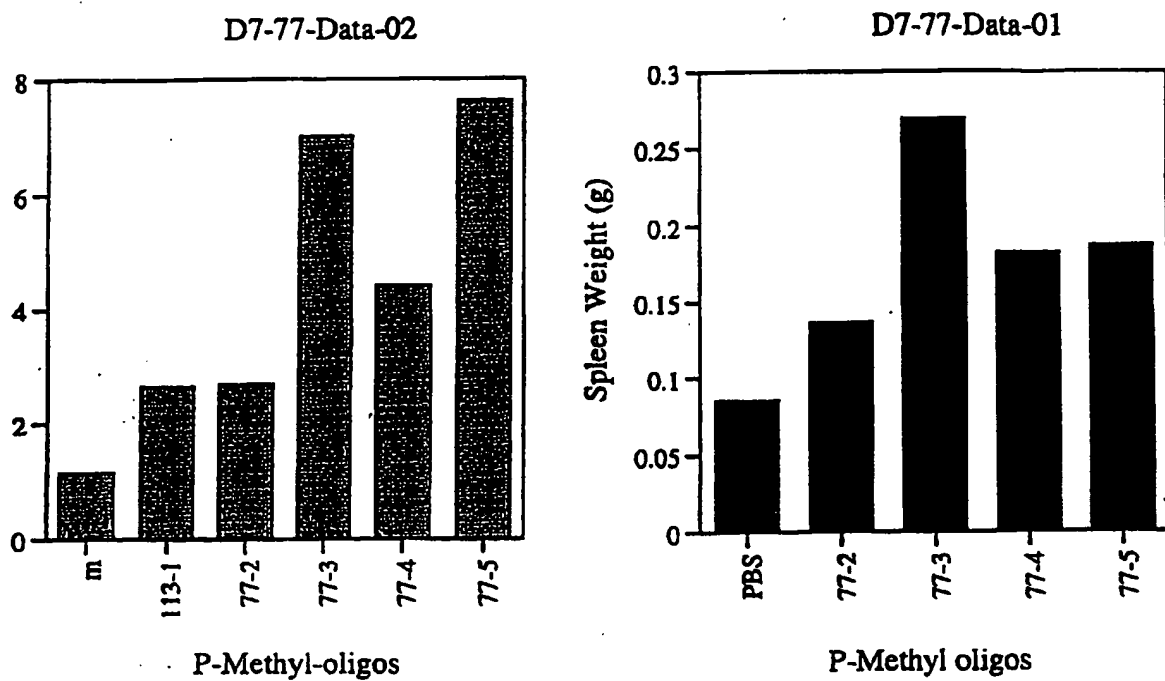


FIGURE 2

3/3



113-1 TCCATGACGTTCTGATGC

77-2 TCCATGACGTTCTGATGC77-3 TCCATGACGTTCTGATGC77-4 TCCATGACG TCTGATGC77-5 TCCATGACGT TCTGATGC

FIGURE 3

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
2 August 2001 (02.08.2001)

PCT

(10) International Publication Number  
**WO 01/55370 A3**

(51) International Patent Classification: C12N 15/11,  
C07H 21/00, A61K 31/7125

(21) International Application Number: PCT/US01/02681

(22) International Filing Date: 26 January 2001 (26.01.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:  
60/178,562 26 January 2000 (26.01.2000) US

(71) Applicant: HYBRIDON, INC. [US/US]; 345 Vassar  
Street, Cambridge, MA 02139 (US).

(72) Inventor: AGRAWAL, Sudhir; 61 Lamplighter Drive,  
Shrewsbury, MA 01545 (US).

(74) Agents: KEOWN, Wayne, A. et al.; Hale and Dorr LLP,  
60 State Street, Boston, MA 02109 (US).

(81) Designated States (*national*): AE, AL, AM, AT, AU, AZ,  
BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK,  
DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL,  
IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU,  
LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT,  
RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA,  
UG, UZ, VN, YU, ZA, ZW.

(84) Designated States (*regional*): ARIPO patent (GH, GM,  
KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian  
patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European  
patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE,  
IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF,  
CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:  
— with international search report

(88) Date of publication of the international search report:  
17 January 2002

*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*



WO 01/55370 A3

(54) Title: MODULATION OF OLIGONUCLEOTIDE CpG-MEDIATED IMMUNE STIMULATION BY POSITIONAL MODIFICATION OF NUCLEOSIDES

(57) Abstract: The invention provides methods for modulating the immune response caused by CpG-containing oligonucleotides. The methods according to the invention enable both decreasing the immunostimulatory effect for antisense applications, as well as increasing the immunostimulatory effect for immunotherapy applications.

# INTERNATIONAL SEARCH REPORT

In. .ational Application No

PCT/US 01/02681

**A. CLASSIFICATION OF SUBJECT MATTER**  
 IPC 7 C12N15/11 C07H21/00 A61K31/7125

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)  
 IPC 7 C12N C07H A61K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, BIOSIS, CHEM ABS Data, MEDLINE

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	ZHAO Q ET AL: "Site of Chemical Modifications in CpG Containing Phosphorothioate Oligodeoxynucleotide Modulates its Immunostimulatory Activity" BIOORGANIC & MEDICINAL CHEMISTRY LETTERS, vol. 9, no. 24, 20 December 1999 (1999-12-20), pages 3453-3458, XP004185533 ISSN: 0960-894X the whole document	1-15, 24-52
X	US 5 886 165 A (AGRAWAL SUDHIR ET AL) 23 March 1999 (1999-03-23) figure 1	55,57,58
Y	column 3, line 43 -column 6, line 40 --- -/--	1-15, 38-52

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

\* Special categories of cited documents :

- \*A\* document defining the general state of the art which is not considered to be of particular relevance
- \*E\* earlier document but published on or after the international filing date
- \*L\* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- \*O\* document referring to an oral disclosure, use, exhibition or other means
- \*P\* document published prior to the international filing date but later than the priority date claimed

- \*T\* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- \*X\* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- \*Y\* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- \*G\* document member of the same patent family

Date of the actual completion of the international search

17 August 2001

Date of mailing of the international search report

29. 08. 2001

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2  
 NL - 2280 HV Rijswijk  
 Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,  
 Fax: (+31-70) 340-3016

Authorized officer

Andres, S



# INTERNATIONAL SEARCH REPORT

In International Application No

PCT/US 01/02681

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 98 49288 A (HYBRIDON INC) 5 November 1998 (1998-11-05)	28-33
Y	page 11, last paragraph -page 12 claims	24-37
X	WO 98 00564 A (ALUL RUSHDI ;BHAN PURSHOTAM (US); DYAD PHARMACEUTICAL CORP (US)) 8 January 1998 (1998-01-08)  page 18, line 10 -page 22 example 10 claims	6-10, 18-21, 43-47, 55-58
X	AGRAWAL S: "IMPORTANCE OF NUCLEOTIDE SEQUENCE AND CHEMICAL MODIFICATIONS OF ANTISENSE OF OLIGONUCLEOTIDES" BIOCHIMICA ET BIOPHYSICA ACTA, vol. 1489, 1999, pages 53-68, XP000979472 ISSN: 0006-3002 Table 1, Oligo 14	28-30, 32
A	KUMAR P ET AL: "Properties of Mixed Backbone Oligonucleotides Containing 3'-O-Methyl Ribonucleosides" BIOORGANIC & MEDICINAL CHEMISTRY LETTERS, vol. 9, no. 17, 6 September 1999 (1999-09-06), pages 2515-2520, XP004188854 ISSN: 0960-894X cited in the application	
A	ZHAO Q ET AL: "EFFECT OF DIFFERENT CHEMICALLY MODIFIED OLIGODEOXYNUCLEOTIDES ON IMMUNE STIMULATION" BIOCHEMICAL PHARMACOLOGY, vol. 51, no. 2, 26 January 1996 (1996-01-26), pages 173-182, XP000610208 ISSN: 0006-2952	
A	KRIEG, A.: "Leukocyte stimulation by oligodeoxynucleotides." STEIN, C. & KRIEG, A. (EDS): "APPLIED ANTISENSE OLIGONUCLEOTIDE TECHNOLOGY", 1998, pages 431-448, XP002131392 US, NEW YORK, WILEY-LISS ISBN: 0-471-17279-0	

-/--

# INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 01/02681

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>PISETSKY DAVID S ET AL: "Influence of backbone chemistry on immune activation by synthetic oligonucleotides."            BIOCHEMICAL PHARMACOLOGY,            vol. 58, no. 12,            15 December 1999 (1999-12-15), pages            1981-1988, XP001015873            ISSN: 0006-2952</p> <p>----</p>	
P,X	<p>ZHAO Q ET AL: "Immunostimulatory activity of CpG containing phosphorothioate oligodeoxynucleotide is modulated by modification of a single deoxynucleoside"            BIOORGANIC &amp; MEDICINAL CHEMISTRY LETTERS,            vol. 10, no. 10, May 2000 (2000-05), pages            1051-1054, XP004204603            ISSN: 0960-894X            the whole document</p> <p>-----</p>	<p>1-23,            38-60</p>

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US 01/02681

## Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☒ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:  
  
Although claims 13-15, 22-23, 34-37, 50-52 and 59-60 are directed to a method of treatment of the human/animal body, the search has been carried out and based on the alleged effects of the compound/composition.
2. ☐ Claims Nos.:  
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

## Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☒ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-15,38-52

Method for reducing the immunostimulatory effect of a CpG-containing oligonucleotide by introducing a 3'-substitution 5'-adjacent to the CpG, the oligonucleotides per se and their use as antisense agents in a method for reducing the expression of a gene in a mammal.

2. Claims: 16-23,53-60

Method for increasing the immunostimulatory effect of a CpG-containing oligonucleotide by introducing 3'-substitutions in positions 3 to 6 in 5' or 3' direction relative to the CpG, the oligonucleotides per se and their use in a method for inducing an immune response in a mammal.

3. Claims: 24-37

Method for increasing the immunostimulatory effect of a CpG-containing oligonucleotide by introducing an uncharged internucleoside linkage in positions 3 to 6 in 5' or 3' direction relative to the CpG, the oligonucleotides per se (with exception of those covered by Subject 2.) and their use in a method for inducing an immune response in a mammal.

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 01/02681

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5886165 A	23-03-1999	NONE	
WO 9849288 A	05-11-1998	AU 7171298 A EP 0991755 A	24-11-1998 12-04-2000
WO 9800564 A	08-01-1998	US 5532130 A AU 6674696 A	02-07-1996 21-01-1998